Research of oxyhydrogen gas mixture influence upon diesel engine performance

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Abstract. The paper presents the results from testing a Volkswagen 1.9 D diesel engine on a test bench to work on gas-diesel cycle with oxyhydrogen gas mixture. Experimental research is done to show the impact of oxyhydrogen gas mixture on engine consumption and environmental indexes such as: fuel and specific fuel consumption; carbon monoxide; carbon dioxide; oxides of nitrogen; smoke emissions. The oxyhydrogen gas mixture delivered to the engine intake manifold with constant flow rate. The results are obtained under research contract № 6524-4/2016.

1 Introduction

Oxyhydrogen gas mixtures (OHGM) are also known as "Brown's Gas" (BG) or "Gas of Brown". According to data from internet sources – [1, 2] Ilia Valkov is considered to be Brown's gas discoverer. He emigrates in Australia at the end of the 1950s, where he lived and worked under the name of Yull Brown.

Oxyhydrogen gas fuel mixture is produced in generators, where electrolysis of sodium or potassium hydroxide water solution as well as some salts takes place [3, 4, 5]. As a result of the inside generator processes a gas mixture from hydrogen and oxygen is released in a volumetric ratio of two to one.

In burner combustion conditions Brown's gas flame temperature can reach very high values and for this reason it has found its application in a variety of technological processes like: cutting, melting, welding etc. – [3, 6].

In the past decade a number of companies have started manufacturing and offering oxyhydrogen fuel mixture generators, intended for mounting on transport vehicles with internal combustion engines. The generated OHGM is delivered to the common part of engine inlet manifold and serves as extra fuel [1, 5, 7]. A small gas volumetric fuel rate delivered from generator is the main problem of applying OHGM as extra fuel in internal combustion engines.

A Bulgarian company – "New Energy Corporation" has designed their own generator, with relatively big overall dimensions and with a maximum fuel flow rate of OHGM – 12 m^3/h (200 l/min). The generator with the abbreviation *VST-4C* is shown at Fig. 1.

Oxyhydrogen gas mixture production is carried out through the electrolysis of a five percent water solution of potassium hydroxide. Distilled water, purified in a special way, is used. Oxyhydrogen gas mixture is produced in the generator compartment, which consists of four working cells; gas separating section; main fluid circulation pump and a cooling system. The generator part of the system is powered with a single phase alternating voltage of 220 V. The maximum electrical power, consumed by the generator is 6 kW.

Fig. 1. Generator of oxyhydrogen gas mixture *VST-4C*, product of "*New Energy Corporation*".

The VST-4C generator is equipped with automatics that control and govern some crucial system parameters: system pressure; work processes temperature; flow rate of OHGM; pressure hysteresis of OHGM; electrolyte level; OHGM gas leakage; flowing electric currency magnitude; cooling system-turn on and off; functionality of electric driven elements etc.

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2 Research point

The aim of the present research is to determine the impact of the oxyhydrogen gas mixture, delivered to common part of the inlet manifold, on diesel engine consumption and environmental indexes.

3 Object of research and methods

3.1. Object of research

Four cylinder four stroke diesel engine *Volkswagen 1,9 D* has been chosen for the experiment with parameters and indexes as follows: cubic capacity – $i.V_h = 1{,}896\ dm^3$; compression ratio – $\varepsilon = 22{,}5$; brake power – $P_e = 47$ kW at speed $n = 4400\ min^{-1}$. This is a swirl chamber engine equipped by the manufacturer with a distributor type fuel injection pump. Oxyhydrogen gas mixture is delivered to the inlet manifold entry through an additionally machined port mounted on the engine. A picture of the experimental engine is shown in Fig.2.

Fig. 2. Picture of the experimental engine.

3.2 Research method

To obtain four load characteristics at engine speed of rotation – $n = 2000\ min^{-1}$ is at the core of the research methodology. The first one is the so called basis – engine runs with standard diesel fuel and the other three are for comparison.

The data for two of the comparison load characteristics are taken with engine running on gas-diesel cycle (GDC) with oxyhydrogen gas mixture at two different flow rates of gaseous fuel.

In each of these characteristics OHGM volumetric flow is constant, despite the engine load. The third load characteristic data is from running the engine on standard diesel fuel, but after one hour operation on gas-diesel cycle with OHGM.

It is necessary to obtain data for the last characteristic so that the subsequent effect of OHGM on diesel engine effective indexes can be weighed up. It is stated [4] that OHG and water steam – the result of gas burning process, have the effect of cleaning soot and tar deposition on the piston, cylinder, engine valves and engine fuel system (injection nozzle holes). It is also known [8] that accumulation of carbon and tar deposit to above mentioned elements leads to worse engine technical condition.

From putting together the test results, the characteristics data are taken under the following conditions:

- same adjustment (according to manufacturer prescriptions) of valve-gear mechanism and engine fuel system;
- same engine heat condition (same temperature of cooling liquid and engine oil);
- same weather conditions i.e. obtain the characteristics data the same day.

4 Test results

The tests were carried out at 50 kW test laboratory of "Combustion Engines, Automobile Engineering and Transport" Department in TU-Sofia equipped with electric constant current dynamometer test bench type *SAK*-50. The test bench makes it possible to measure engine effective power indexes.

The calculation of fuel consumption and specific diesel fuel consumption is carried out by means of fuel flow meter that measures the time for the consumption of the exact volume of liquid fuel by the engine. The diesel fuel flow meter is engineered at the Department of Combustion Engines, Automobile Engineering and Transport in TU-Sofia, and the volume of consumed diesel fuel is read with an accuracy of $0{,}2\ cm^3$.

The oxyhydrogen gas volumetric flow rate is to be measured with gas flow meter type *SD 5000* of the *IFM* company (Germany).

Boston gas-analyzer of *Tecno control* (Italy) and smoke meter "*EFAW 68A*" of *Bosch* (Germany) are used for measuring the engine environmental indexes. The gas-analyzer reads the following components in the engine exhaust emissions: carbon monoxide – CO (accuracy 1 ppm); carbon dioxide – CO_2 (accuracy 0,1 %); nitrogen monoxide – NO (accuracy 1 ppm); oxides of nitrogen – NO_x (accuracy 1 ppm); oxygen with an accuracy of 0,2 points.

A type K thermocouple and electronic measuring instrument with an accuracy of 1 °C has been used to measure the exhaust gas temperature. The thermocouple is mounted on engine exhaust manifold, at a distance of 100 mm from the outlet collector flange.

Most of the results are shown in Fig. 3 to Fig. 12, where additional abbreviations are used:

- n – engine speed, min^{-1};
- p_e – mean effective pressure, MPa;
- B_{hdf} – engine fuel consumption (diesel fuel), kg/h;
- b_{edf} – specific fuel consumption (diesel fuel), g/kWh;
- T_{EG} – exhaust gas temperature, °C;
- Q_{HHO} – volumetric flow rate of oxyhydrogen gas mixture, l/min;
- R_b – smoke emissions (Bosch Smoke Number).

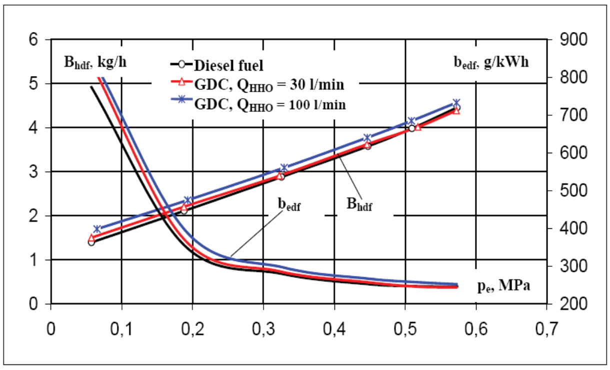

Fig. 3. Effect of OHGM on the fuel consumption of diesel engine *Volkswagen* – 1,9 D at speed n = 2000 min^{-1}.

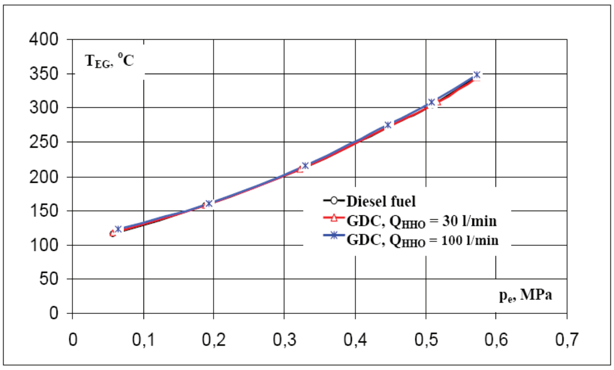

Fig. 4. Effect of OHGM on exhaust gas temperature of diesel engine *Volkswagen* – 1,9 D at speed n = 2000 min^{-1}.

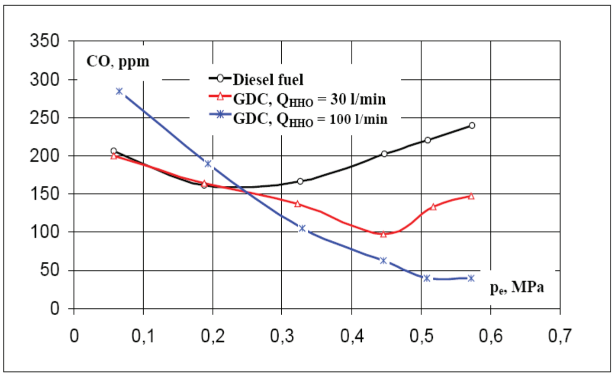

Fig. 5. Effect of OHGM on carbon monoxide emissions of diesel engine *Volkswagen* – 1,9 D at speed n = 2000 min^{-1}.

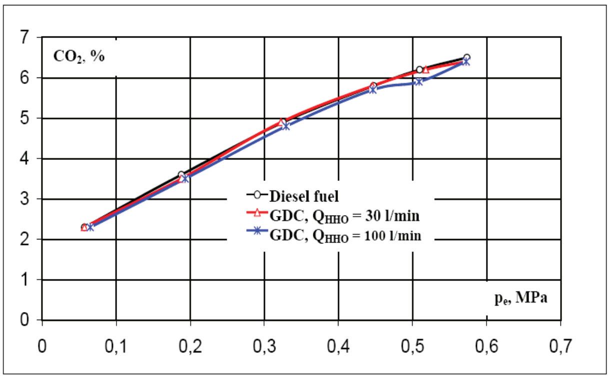

Fig. 6. Effect of OHGM on carbon dioxide emissions of diesel engine *Volkswagen* – 1,9 D at speed n = 2000 min^{-1}.

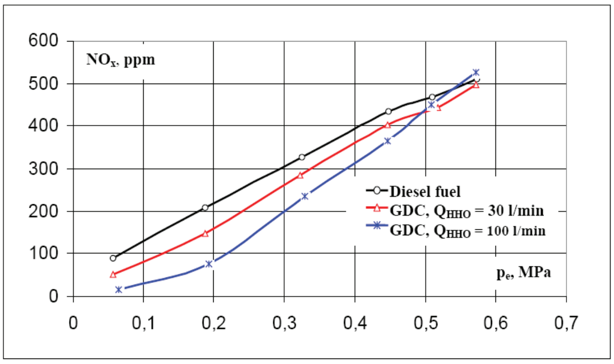

Fig.7. Effect of OHGM on oxides of nitrogen emissions of diesel engine *Volkswagen* – 1,9 D at speed n = 2000 min^{-1}.

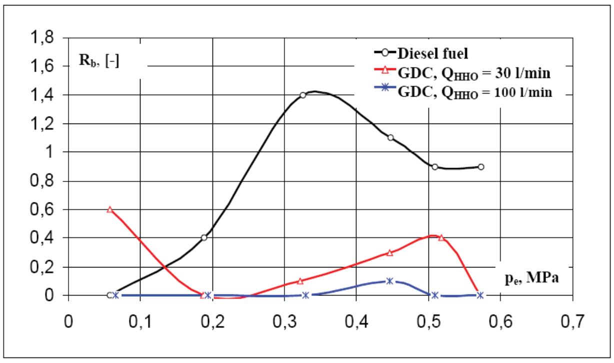

Fig. 8. Effect of OHG on smoke emissions of diesel engine *Volkswagen* – 1,9 D at speed n = 2000 min^{-1}.

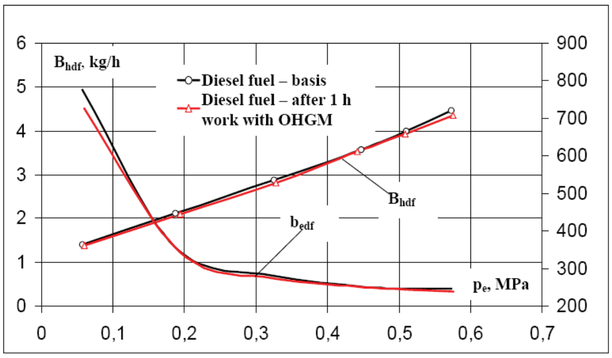

Fig.9. Comparison of fuel consumption of diesel engine *Volkswagen* – 1,9 D at speed n = 2000 min^{-1} after 1 hour running with OHGM.

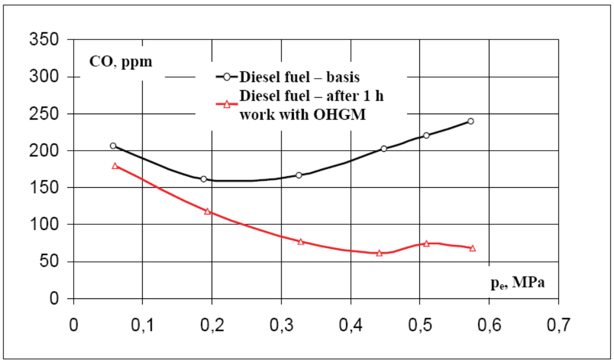

Fig.10. Comparison of carbon oxide emissions of diesel engine *Volkswagen* – 1,9 D at speed n = 2000 min^{-1} after 1 hour running with OHGM.

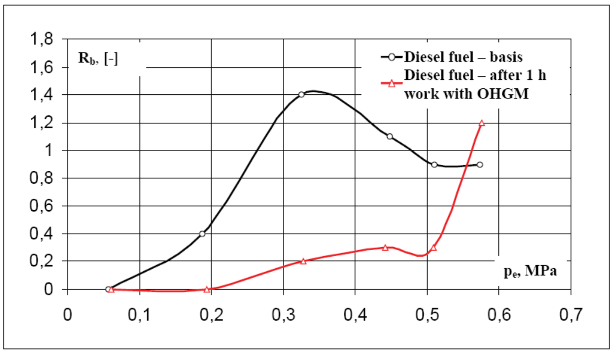

Fig.11. Comparison of exhaust gas smoke emissions of diesel engine *Volkswagen* – 1,9 D at speed $n = 2000$ min^{-1} after 1 hour running with OHGM.

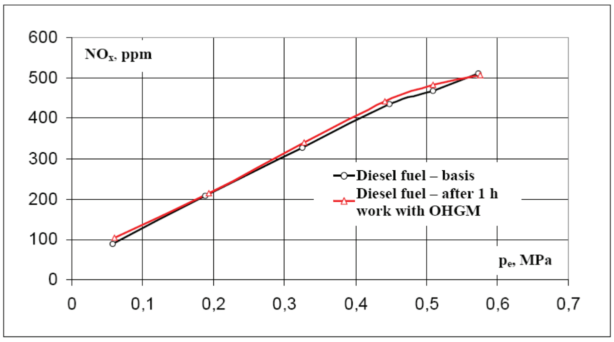

Fig. 12. Comparison of oxides of nitrogen emissions of diesel engine *Volkswagen* – 1,9 D at speed $n = 2000$ min^{-1} after 1 hour running with OHGM.

The impact of oxyhydrogen gas mixture on engine consumption indexes has been studied through a comparison of the corresponding diesel fuel consumption and specific diesel fuel consumption. This comparison method results from the fact that the composition and physical properties of the thus generated oxyhydrogen gas mixture are not defined in advance, so although the volumetric flow rate is known – the mass flow rate cannot be calculated. On the other hand, this allows for a comparison of the obtained data with other authors [9].

A watt-hour meter was used during the experimental research to measure the electric energy consumed by the oxyhydrogen gas mixture generator – E_{HHO}. With a volumetric flow rate of OHGM – $Q_{\mathrm{HHO}} = 30$ l/min consumed electric energy is 0,82 kWh and with a volumetric flow rate of $Q_{\mathrm{HHO}} = 100$ l/min – $E_{\mathrm{HHO}} = 2{,}69$ kWh respectively.

The analysis of the experimental results of running the engine on a gas-diesel cycle with oxyhydrogen gas mixture at the thus examined engine rotation speed shows:

- at a volumetric flow rate of oxyhydrogen fuel gas mixture - $Q_{\mathrm{HHO}} = 100$ l/min there is obvious reduction in fuel consumption – B_{hdf} and specific fuel consumption – b_{edf} of diesel fuel, respectively to 4 % and to 15,7 %, when running the engine on a gas-diesel cycle with OHG as compared to running with standard diesel fuel;
- at a volumetric flow rate of oxyhydrogen gas mixture – $Q_{\mathrm{HHO}} = 30$ l/min there is no significant difference in engine consumption;
- change of carbon monoxide emissions – *CO* are not one-sided. At small engine loads carbon monoxide emissions are lowered by up to 29 % when running the engine with standard diesel fuel as compared to running the engine on a gas-diesel cycle with a volumetric flow rate of OHGM – $Q_{\mathrm{HHO}} = 100$ l/min. Under the same load conditions the alterations of carbon monoxide emissions when running the engine with standard diesel fuel and running the engine on gas-diesel cycle with volumetric flow rate of OHGM – $Q_{\mathrm{HHO}} = 30$ l/min are negligible. At middle and high engine loads considerable decrease of carbon monoxide emissions is observed – when running the engine at gas-diesel cycle with volumetric flow rate of OHGM – $Q_{\mathrm{HHO}} = 100$ l/min as compared to running on standard diesel fuel and running on gas-diesel cycle with volumetric flow rate of OHGM – $Q_{\mathrm{HHO}} = 30$ l/min – up to 6 times and up to 3,7 time respectively;
- oxides of nitrogen emissions NO_x – when running the engine on gas-diesel cycle with oxyhydrogen volumetric flow rate – $Q_{\mathrm{HHO}} = 100$ l/min are significantly as compared to running with standard diesel fuel and running on gas-diesel cycle with OHGM volumetric flow rate – $Q_{\mathrm{HHO}} = 30$ l/min – respectively: up to 2,7 times and up to 1,9 times;
- exhaust gas smoke emissions R_{b} – when the engine is running on gas-diesel cycle with volumetric flow rate of OHGM – $Q_{\mathrm{HHO}} = 100$ l/min, as well as with volumetric flow rate of OHGM – $Q_{\mathrm{HHO}} = 30$ l/min – they are significantly lower as compare to running the engine with standard diesel fuel – up to 1,4 times. When the engine runs on a gas-diesel cycle with volumetric flow rate of OHGM – $Q_{\mathrm{HHO}} = 100$ l/min exhaust gas smoke – R_{b} is up to 30 % lower as compared to running the engine on gas-diesel cycle with volumetric flow rate of OHGM – $Q_{\mathrm{HHO}} = 30$ l/min;
- emission variations of carbon dioxide – CO_2 and free oxygen O_2 in engine exhaust gas when running on standard diesel fuel and running on gas-diesel cycle with OHGM are defined by measurement accuracy;
- there are no variations in engine exhaust gas temperature when running with standard diesel fuel or gas-diesel cycle with oxyhydrogen gas mixture.

These experimental results of engine running with standard diesel fuel and speed of rotation $n = 2000$ min^{-1}, but after one hour running on gas-diesel cycle with OHGM, leads to the following conclusions:

- there is improvement in the engine consumption indexes of up to 3 %;
- there is essential decrease of emissions of carbon monoxide in engine exhaust gas – up to 70 %;
- many times decrease of engine exhaust gas smoke – up to 7 times;
- changes in the rest of the engine environmental indexes are negligible.

5 Conclusion

The analysis of the results of the experimental research leads to the conclusion that oxyhydrogen gas mixtures can be used in practice as extra fuel for diesel internal combustion engines, since the use of such gases leads to improvement of the engine environmental and, in the case of sufficient flow rate, consumption indexes. In the future there should be research of the methods and technical instruments for developing powerful oxyhydrogen gas mixture generators with acceptable dimensions so that they can be used on transport vehicles, set in motion by internal combustion engines.

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